Development of a National Littoral Ocean Observing and Prediction System: Field Estimation via Interdisciplinary Data Assimilation: Turbulence Characterization from an AUV

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LONG-TERM GOAL

My long term scientific goal is to understand coastal mixing processes, utilizing turbulence measurements obtained from small Autonomous Underwater Vehicle (AUV) based sensors, and to contribute to the improvement of subgrid characterization in combined coastal ocean observation/prediction networks.

OBJECTIVES

Within the context of the Cape Cod Bay/Mass. Bay based National Ocean Partnership Program (NOPP) coupled ocean observation/modeling system, I use AUV-based turbulence measurements to quantify mixing in shallow water physical process studies (gyres, fronts. boundary layers). This includes identifying regions of enhanced mixing, determining the horizontal spatial scale of mixing events, defining the role of boundary layers, and parameterizing results for coastal predictive model testing studies of subgrid scale processes.

APPROACH

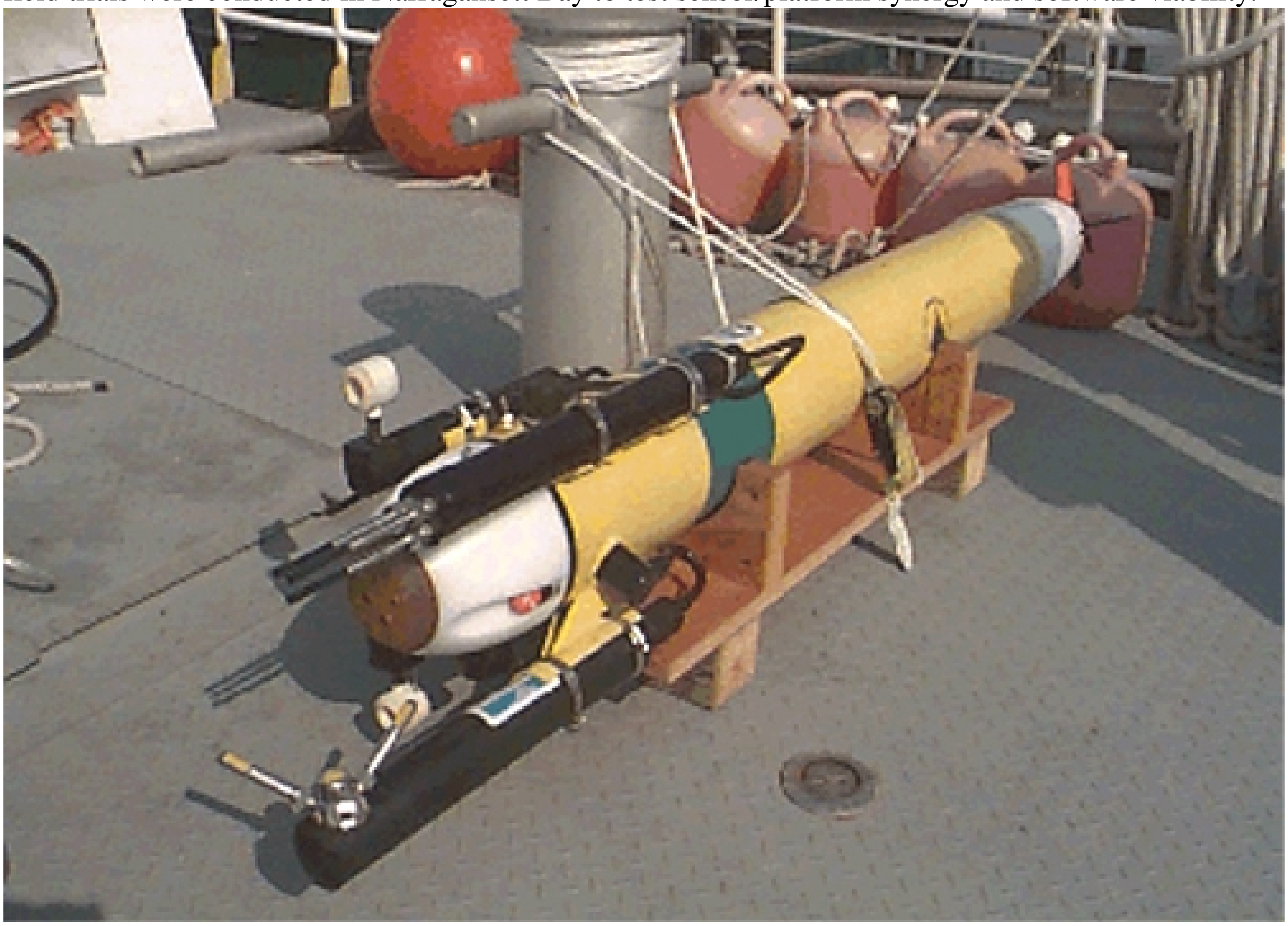
My approach is to integrate an optimum turbulence sensor suite into a small, logistically simple, AUV, with input from the ocean turbulence and modeling communities. Then, I establish this small AUV as a viable platform for coastal turbulence research. Towards this end, I obtain horizontals profiles of dissipation rate, temperature microstructure, 3-dimensional small scale velocity, finescale vertical shear of horizontal current, and stratification in the coastal environment.

Subsequently, I studied mixing in the context of the multi-scale measurements surrounding the Littoral Ocean Observation and Prediction System (LOOPS) site in Cape Cod Bay/Mass. Bay. I sampled adaptively using a continental shelf model, the HOPS model (Lozano et al, 1996).

The sensors provided data for estimates of eddy diffusivity profile (Gargett and Moum (1995), eddy viscosity profile (using the truncated TKE equation), Richardson number, and fluxes [using the correlation technique]. These data enable us to evaluate to tune and improve filter parameters in the HOPS numerical model.

WORK COMPLETED

We electrically and mechanically integrated a turbulence sensor package was into the REMUS AUV (Levine and Lueck, 1999) (Fig 1). Sensors include two shear probes, an ultra-fast thermistor, an upward and downward looking ADCP, two vertically separated CTDs, and an ADV-O. Preliminary field trials were conducted in Narragansett Bay to test sensor/platform synergy and software viability.



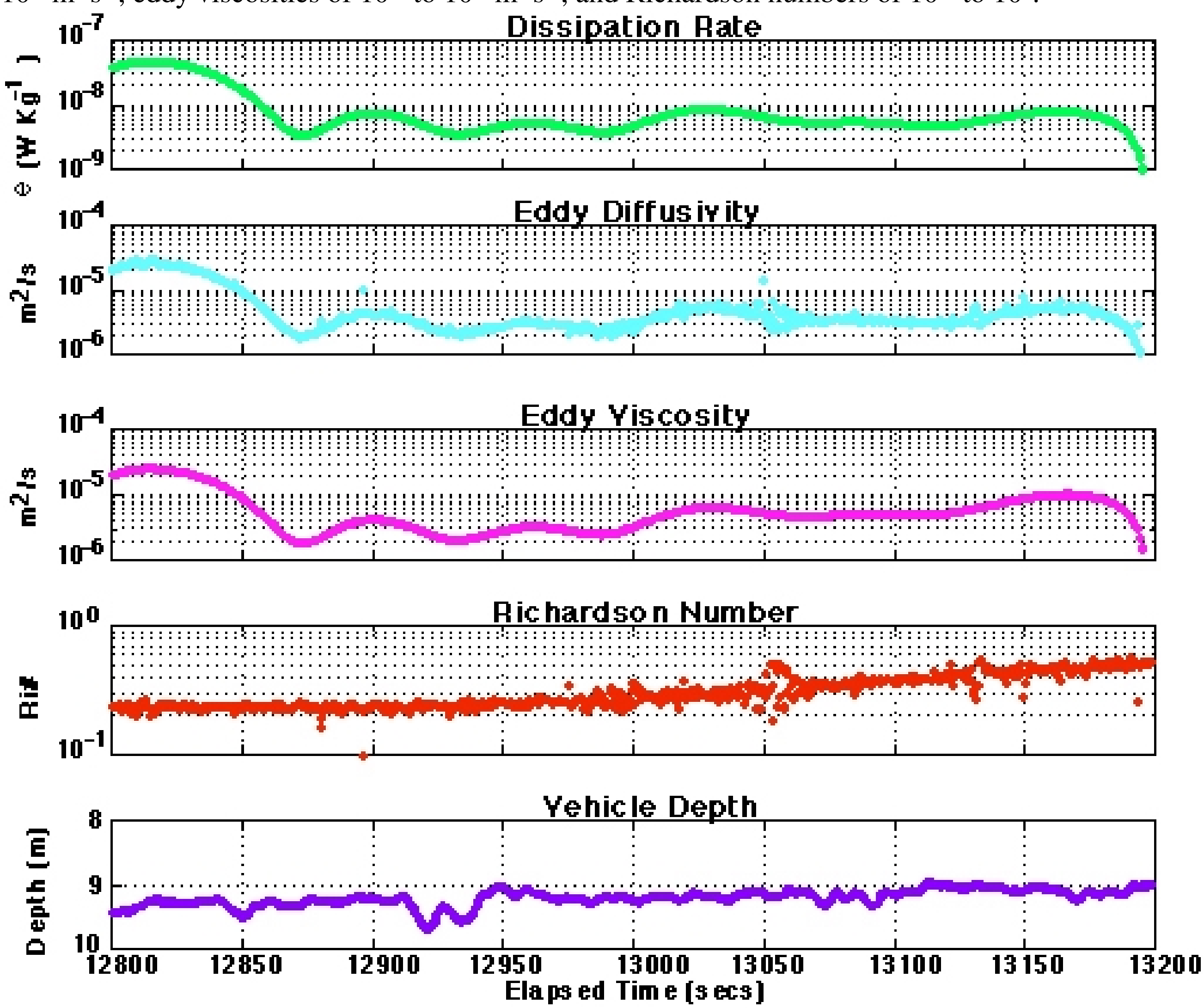
1. The REMUS AUV instrumented with turbulence sensors

Utilizing these techniques, we conducted scientific studies during varied circulation patterns in the LOOPS region of study in Cape Cod Bay during September 1998, including an upwelling event. Harvard model forecasts concentrate on a multiscale examination of the patchiness of the biological/physical regime that supports zooplankon layers associated with right whale feeding in Cape Cod Bay (relate patchiness to dispersion processes). In the field experiment, high quality data were obtained from all sensors, and data analysis is proceeding well.

RESULTS

Using model-based adaptive sampling, the AUV was deployed along a trajectories through components of Cape Cod Bay general circulation, including the upwelling region and the gyre center. These measurements were made synoptically with those from other platforms which characterize larger scale structures in nearby Cape Cod Bay and the larger Mass. Bay influences. Model predictions which include assimilated data from the wide variety of sampling platforms is also available for comparison, including shipboard, satellite and Odyssey AUV data acquisition .The turbulence sensor instrumented REMUS provided the smallest of the nested scales

For the Cape Cod Bay data, results indicate that the modified REMUS AUV was a viable platform for turbulence data acquisition in the coastal ocean, with good data obtained from all sensor systems. The shear probe data are processed to remove noise associated with vehicle vibrations. This process is done using data from accelerometers located in the probe pressure case directly behind the probe mounts, utilizing the techniques of Levine and Lueck (1999). Consistently, comparisons of computed autospectra agree well with the Nasmyth "universal spectrum" (Oakey, 1982) out to wavenumbers close to the physical size of the sensing tip of the shear probes. An example of the Cape Cod Bay turbulence estimation is shown in Fig 2. For a 9 m depth transit near Provincetown harbor, time series of mixing parameter estimates show dissipation rates of 10^{-9} to 10^{-8} W kg^{-1}, eddy diffusivities of 10^{-6} to 10^{-5} m^2 s^{-1}, eddy viscosities of 10^{-6} to 10^{-5} m^2 s^{-1}, and Richardson numbers of 10^{-1} to 10^{0}.



2. Northern Cape Cod Bay mixing parameters, Sept. 24, 1998

IMPACT/APPLICATION

The AUV-based turbulence measurements provide a unique horizontal profiling view of the variability of the mixing environment that cannot be obtained by more conventional sampling measurements, and this approach can be further exploited in yo-yoed horizontal sections. These techniques will be invaluable in upwelling process studies in which competing alternatives are testing in HOPS to parameterize subgrid processes according to the Shapiro filter tuning of Lermusiaux, (1997) or other methods (Chassignet and Verron, 1998)

TRANSITIONS

Our AUV sensor technologies, hardware and software, are being considered for inclusion as tactical oceanography payloads for the Manta UUV Initiative.

RELATED PROJECTS

Our AUV-based turbulence measurement system is also being utilized in NOPP studies with the Rutgers University led project at LEO-15, where measurements were also made in the Mid-Atlantic Bight in July 1998 and July 1999. The system is also being utilized in NOPP FRONT studies on the New England continental shelf during 1999-2001.

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